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Intervening to reduce workplace sitting time: how and when do changes to sitting time occur?

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ABSTRACT

Objective To investigate how and when changes in workplace sitting time occurred following a workplace intervention to inform evaluation of intervention success.

Method The 4-week Stand Up Comcare study (June–September 2011) aimed to reduce workplace sitting time via regularly interrupting and replacing sitting time throughout the day. Activity monitor (activPAL3) workplace data from control (n=22) and intervention participants (n=21) were analysed. Differences in the number and usual duration of sitting bouts were used to evaluate how change occurred. To examine when change occurred, intervention effects were compared by hour since starting work and hour of the workday. Change in workplace activity (sitting, standing, stepping) was examined to further inform alignment with intervention messages. Individual variability was examined in how and when the change occurred.

Results Overall, behavioural changes aligned with intervention aims. All intervention participants reduced total workplace sitting time, though there was wide individual variability observed (range −29 to −262 min per 8 h workday). On average, intervention participants reduced number of sitting bouts (−4.6 bouts (95% CI −10.1 to 1.0), p=0.106) and usual sitting bout duration (−5.6 min (95% CI −9.8 to −1.4, p=0.011)) relative to controls. Sitting time reductions were observed across the workday, though intervention effects varied by hour of the day (p=0.015). The intervention group successfully adopted the *Stand Up* and *Sit Less* intervention messages across the day.

Conclusion These analyses confirmed that this workplace intervention successfully modified sitting behaviour as intended (ie, fewer and shorter sitting bouts, with changes occurring throughout the day).

INTRODUCTION

Recognition of the detrimental health impacts of excessive sitting has led to the development and implementation of interventions specifically targeting this common health behaviour.[1–5] A key setting for interventions has been the office workplace,[6] with several interventions successfully reducing total workplace sitting time.[7–10] However, little is known about how the reduction is achieved (ie, via reducing the number and/or duration of sitting bouts) or when the changes occur (ie, across the whole day or at distinct times of the day). This is of particular importance in view of the detrimental cross-sectional associations of fewer breaks in sitting time (independent of total amount) with cardiometabolic biomarkers[11 12]; the acute detrimental effects of prolonged, unbroken sitting observed within experimental studies;[13 14] and, the temporal variations that have been observed cross-sectionally in office workers' sedentary time.[15] The detailed examination of data from activity monitors—particularly those with direct postural measures and date-stamped and time-stamped data[16]—can elucidate this information. More detailed reporting on these issues is crucial in evaluating the success of interventions (ie, did the changes observed correspond with the intervention messages?) and informing further intervention refinement. To date, however, the findings from intervention trials to reduce sitting time have primarily been limited to the reporting of changes in total sitting time.[7–9]

The Stand Up Comcare trial, a non-randomised workplace intervention in office workers, achieved a reduction in total workplace sitting time of more than 2 h/8 h workday in the intervention group relative to controls.[8] The key intervention messages were to *Stand Up* (ie, reduce duration of sitting bouts; increase standing time), *Sit Less (*ie, reduce total sitting time and the number of sitting bouts) and *Move More* (ie, increase incidental physical activity), with changes made regularly throughout the day.

In reducing total workplace sitting time, participants may have adopted one or all of the intervention messages, or components of each. For example, it is plausible that while reducing total workplace sitting time, participants may have reduced sitting time in the morning and continued to sit for prolonged periods in the afternoon; alternatively, they may have reduced the number of sitting bouts (ie, they may have had a standing meeting), but not reduced the duration of the sitting bouts. In each of these scenarios, the participants may have adopted components of the *Stand Up* and *Sit Less* messages, but not incorporated these changes regularly across the day.

It is important to understand what sitting time was replaced with (ie, standing or stepping) and—given the potential detrimental effects of prolonged, unbroken standing[17]—it is also important to understand the duration of standing or stepping that is replacing the sitting time. Such information is not possible to ascertain from examining total change in workplace sitting time alone. Therefore, the aims of this study were to investigate how (ie, via reducing the number and/or duration of sitting bouts) and when (ie, across the whole day or at distinct time points) changes in workplace sitting occurred, as well as the individual variability in these changes.

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METHODS

Study design, intervention, participants and recruitment

Stand Up Comcare was conducted in a single workplace (Melbourne, Australia), with intervention participants (n=21) located on a separate floor from controls (n=22). This trial was the pilot study for a larger cluster-randomised trial. The methods and intervention design for this pilot, as well as the larger trial, have been reported in detail elsewhere.[8 18 19] In brief, the multicomponent intervention comprised organisational, environmental and individual behavioural change strategies. These consisted of consultation with management, a workplace information session, installation of sit-to-stand workstations and tailored support for individual behavioural change through goal setting and motivational interviewing.[8] The control group was instructed to continue usual activities. All participants provided written, informed consent.

Data collection

Data were collected at baseline and immediately following the intervention (June–September 2011). At both assessments, participants wore activPAL3 activity monitors (PAL Technologies Limited, Glasgow, UK) continuously for seven consecutive days, recorded their wake/sleep and work times in a diary, and underwent morning anthropometric and fasting blood measurements. Data on sociodemographic (age, gender, ethnicity, educational attainment, employment history, smoking history and medical history) and work characteristics (type of employment and job type) were collected at baseline only.

Instrumentation

The small, unobtrusive, valid and reliable[16 20 21] activPAL3 activity monitor (V.6.3.0; default settings used) was worn 24 h/day. It was waterproofed and secured on the anterior midline of the right thigh. The monitor provides date-stamped and time-stamped data on sitting/lying, standing and stepping (number of steps, stepping cadence).[22]

Statistical analyses

Data were processed in SAS V.9.3 (SAS Institute Inc, Cary, North Carolina, USA) using a customised program that combined participants' diary and activPAL3 data. All statistical analyses were performed in SPSS Statistics Software, V.20 (SPSS, Inc, Chicago, Illinois, USA) or SAS V.9.3 in 2013. Significance was set at $p<0.05$ (two-tailed). Most analyses were limited to participants with valid baseline and follow-up monitor data (n=18 intervention; n=18 controls).

How sitting time reductions occurred

Total workplace sitting time and the number of workplace sitting bouts were calculated for each participant across each day and averaged for valid workdays (days were considered valid if the monitor was worn ≥80% of workplace time). To account for variations in wear time and work hours, these variables were standardised to an 8 h workday. Median sitting bout duration and usual sitting bout duration ($W_{50\%}$)[23] were calculated for each participant based on all bouts on valid workdays. The value for $W_{50\%}$ indicates the bout duration at which 50% of total sitting time is accrued. That is, $W_{50\%}$ is the midpoint of the sedentary accumulation curve as described by Chastin and Granat's[23] equation number seven. Unlike median bout duration, this statistic takes into consideration that the longer the bout, the more it will contribute to total sitting time. Half of all *sitting bouts* are longer than the median, whereas half of all *sitting time* is accrued in bouts longer than the $W_{50\%}$. Each participant's usual bout duration was calculated using non-linear regression (Levenberg-Marquardt algorithm), based on the following sigmoidal-shaped function that characterises sedentary accumulation,[23] where the outcome (y, cumulative proportion of sedentary time accrued in bouts of duration ≤t) is treated as a function of bout duration (t), usual bout duration ($W_{50\%}$) and the free parameter (n) in the form of:

$$y = \frac{t^n}{t^n + W_{50\%}^n}$$

Intervention effects on total workplace sitting time, number of bouts, median bout duration and usual bout duration were examined by linear regression analyses adjusting for baseline values. No potential confounders ($p<0.2$ association with the outcome) were identified.[24] The associations of reductions in number of bouts, usual bout duration and sitting time reductions in the intervention group were then examined using linear regression, with results displayed graphically in a contour map.

Principles from exposure variation analysis[25] were applied to describe changes in intensity, frequency and duration simultaneously as they pertain to uptake of the *Stand Up, Sit Less, Move More* messages. Mean amount of time in minutes was plotted (z axis) for each intensity (sitting, standing, stepping; y axis) at each frequency (bout duration category; x axis) for intervention and control groups at baseline and follow-up. Categories of bout durations were chosen such that, overall at baseline, approximately 25% of each intensity occurred in each of the bout duration categories (accumulation quartiles). The cut-offs for the bout duration categories were chosen to describe the change in activity from baseline to follow-up, unlike the main outcomes paper,[8] which was examining clinical and meaningful outcomes.

When sitting time reductions occurred during the workday

Reductions in sitting time were examined for each participant on each workday. Sitting time (as a percentage) was summarised for each hourly time period during work hours. Hourly time periods were defined by hours since starting work (0 to <1, … ≥8) and by hours of the day (≤8:59, 9:00–9:59,…, ≥17:00). Hours with ≥80% of workplace time monitored were considered valid.

Differences by hourly periods were tested using general linear mixed models, with a compound symmetry within subject covariance structure providing the best fit. These models accounted for repeated measures and included the effects of day, hour, group and timepoint (prepost), with two-way and three-way interactions for group×timepoint×hour. Education was associated with hourly sitting ($p<0.2$)[24] and was adjusted as a confounder. To illustrate the individual variability in the temporal patterning within the intervention group, sitting time (as a percentage) was summarised and plotted for each hour of the day. Participants were stratified by least (n=6), moderate (n=6) and most (n=6) reduction in total workplace sitting time.

RESULTS

Participant characteristics

Participant characteristics are described in online supplemental table S1. The mean age of participants was 43.2 (SD 10.3) years. In the control group, 67% were men, with 86% employed in a professional or managerial position. In the intervention group, 23% of participants were men, with 57% of participants being employed in clerical, service or sales positions.

How sitting time reductions occurred

On average, most (approximately 70%) workplace time at baseline was spent sitting. At baseline, participants' median sitting bout duration averaged 6.2 (SD=3.0) min whereas usual bout duration showed that 50% of total workplace sitting time was accrued in bouts ≥21.9 (SD=7.7) min (table 1). Following intervention, in addition to the significant changes observed for total workplace sitting time (−125.2 min in favour of intervention), significant intervention effects were also observed for usual bout duration (−5.6 min) and median bout duration (−2.8 min). Furthermore, there was a tendency (albeit non-significant: p=0.106) towards greater reductions in number of sitting bouts in intervention versus control participants (−4.6 bouts, 95% CI −10.1 to 1.0).

Following the intervention, all intervention participants reduced total workplace sitting time (range −29 to −262 min per 8 h workday). Over half (56%) of intervention participants achieved some reduction (ie, >0 min or bouts) in both number of sitting bouts and usual bout duration; a third (33%) reduced bout number only; while 11% reduced usual bout duration only. The change in the number of bouts and usual bout duration was significantly and independently associated with change in total workplace sitting time in the intervention group. Specifically, a reduction of one sitting bout was associated with a −7.7 min reduction in total workplace sitting time (95% CI −9.7 to −5.8, p<0.001), while each minute reduction in usual bout duration was associated with a −6.5 min reduction in total workplace sitting time (95% CI −8.9 to −4.0, p<0.001). This relationship is illustrated in figure 1. Here, the shaded contour map illustrates the relationship of change in total workplace sitting time (z axis; dark grey—the greatest reductions, through to light grey—the greatest increases) with change in number of sitting bouts (y axis) and change in usual bout duration (x axis) within the intervention group. The approximately 45° change in the shading shows a shift both vertically (number of sitting bouts) and horizontally (usual bout duration) along the axes, indicating that total workplace sitting time changed similarly with both changes in bout number and usual bout duration.

To illustrate what sitting time was replaced with, figure 2 depicts the shifts in intensity (sitting, standing, stepping) and bout duration from baseline to follow-up. At baseline, the majority of work time was spent sitting, with the remainder primarily spent standing. Minimal changes occurred in the control group across any intensity or duration. For the intervention group, reductions across all sitting bout categories were observed (especially in the longest bouts); these corresponded with increases in standing time (in longer standing bouts) but not changes in stepping time (of any bout duration).

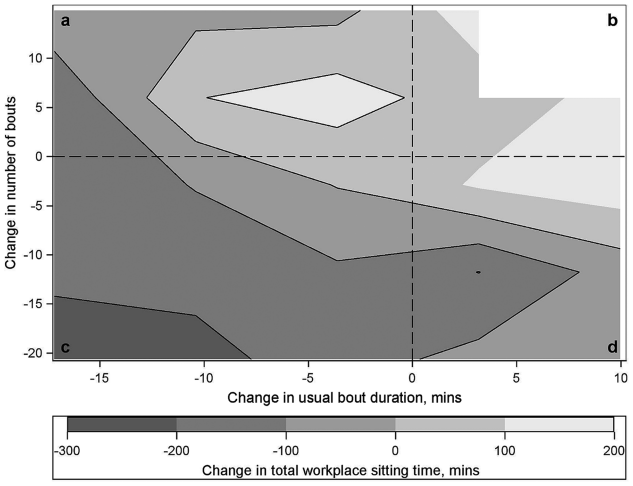


Figure 1 A shaded contour map illustrating the relationship between change in total workplace sitting time (z axis; dark grey—the greatest reductions, through to light grey—the greatest increases) with change in number of sitting bouts (y axis) and change in usual bout duration (x axis) within the intervention group.

When sitting time reductions occurred during the workday

Figure 3 presents the intervention effects on sitting (as a percentage of monitored work time) by hour since starting work (A) and by hour of the workday (B). Intervention effects were significant at each hour since starting work. However, there were no significant (group×timepoint×hour since starting work) interactions. That is, there was no evidence that intervention effects varied by hour since starting work (p=0.648) and differences by hour were not observed for changes in the intervention (p for interaction=0.539) or control (p for interaction=0.539) groups.

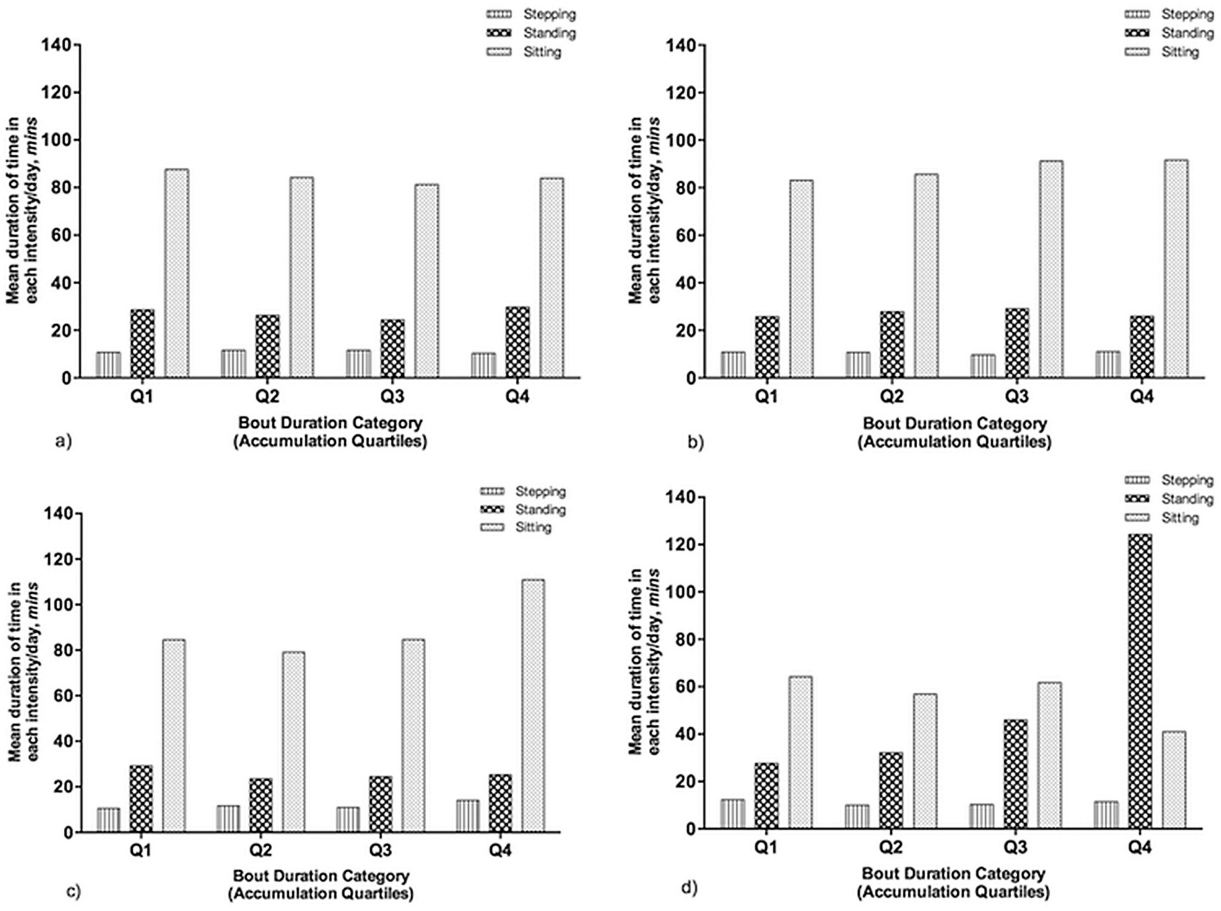
However, intervention effects differed significantly by hour of the day (p=0.015), with changes in percentage of workplace sitting time differing significantly by hour within both intervention (p for interaction=0.014) and control (p for interaction=0.015) groups. Specifically, the intervention group significantly reduced their workplace sitting time at all hours of the workday compared to controls, except for the 12 to 12:59 period. The large differences (≥30% reduction in workplace time spent sitting) were evident before 9:00, from 9 to 9:59 and from 11 to 11:59 (see online supplemental table S2).

While the size of the intervention effects varied by hour of the day, 78% of intervention participants achieved some sitting time reduction (>0 min) across most (≥80%) monitored work hours. Individual change in percentage sitting time per hour is plotted in online supplementary figure S1 for most (n=6),

Table 1 Intervention effects for sitting time, bout number and bout duration in intervention (n=18) versus control (n=18) groups

	Baseline (mean, SD)			Follow-up (adjusted mean, SE)*		Intervention effects		
						Mean difference (intervention−control)*		
Variable	All	Intervention	Control	Intervention	Control	Difference	95% CI	p Value
Total sitting time† (min)	333.4 (46.9)	338.5 (35.3)	334.7 (52.4)	215.4 (12.6)‡	340.6 (12.6)	−125.2	−161.4 to −88.9	<0.001
Number of bouts of sitting† (n)	32.5 (9.5)	31.5 (7.5)	33.0 (11.3)	26.2 (1.9)‡	30.8 (1.9)	−4.6	−10.1 to 1.0	0.106
Median bout duration (min)	6.2 (3.0)	5.7 (2.5)	6.5 (3.3)	3.8 (0.8)‡	6.6 (0.7)	−2.8	−4.9 to −0.7	0.011
Usual bout duration ($W_{50\%}$) (min)	21.9 (7.7)	23.3 (7.3)	21.7 (8.4)	19.2 (1.5)‡	24.8 (1.5)	−5.6	−9.8 to −1.4	0.011

*Adjusted mean difference (95% CI) based on linear regression, adjusted for baseline values of the outcome: 336.6 (total sitting time), 32.3 (number of sitting bouts), 6.2 (median bout duration), 22.5 (usual bout duration).
†Minutes or n per 8 h workday=variable in minutes or n×(8/worn hours).
‡p<0.05 for change from baseline (within groups) estimated by paired t test.



Cut points for bout duration categories, *mins*

	Sitting	Standing	Stepping
Q1	<11.6	<0.7	<0.3
Q2	11.6 to <22.7	0.7 to <1.8	0.3 to <0.7
Q3	22.7 to <40.3	1.8 to <4.7	0.7 to <2.2
Q4	>40.3	>4.7	>2.2

Figure 2 Modified exposure variation analysis[25] graph of the mean duration of time spent across each intensity (sitting, standing, stepping) at each bout duration category (accumulation quartiles), for control and intervention groups (A and B) at baseline, and control and intervention groups (C and D) at follow-up. Overall at baseline, approximately 25% of each intensity occurred in each of the bout duration categories.

moderate (n=6) and least (n=6) reduction in total workplace sitting time. The amount of change in each hour and the temporal patterning across the day was most variable among participants with the most and least reduction in workplace sitting time, and least variable among participants with moderate change.

DISCUSSION

The Stand Up Comcare workplace intervention achieved an average reduction in total workplace sitting time of over 2 h/workday.[8] This study, by examining how and when these changes occurred, has provided important insights into the success of the intervention messages, as well as suggestions for intervention refinement.

Participants stood more and sat less across the workday

Overall, behavioural changes aligned well with intervention aims —particularly the *Stand Up* and *Sit Less* messages. Specifically, all intervention participants reduced their total workplace sitting time, most reduced both the number and the duration of their sitting bouts, these changes occurred across the workday, though there was wide individual variability in these changes. However, as previously noted, there was minimal uptake of the *Move More* message, which may reflect the short duration of incidental activity, and the limited opportunities for this to occur in the office workplace.[8] Further, consistent with the use of sit–stand workstations, sitting time reductions appeared to primarily be achieved by replacing sitting bouts (especially long sitting bouts), with standing bouts. Notably, the increase in time spent standing tended towards longer standing bouts, which may have detrimental health impacts.[17] Thus, future intervention messages could be refined to further identify strategies to encourage and support incidental physical activity, and reiterate regular changes in posture (transitioning to/from sitting and standing).

Implications for future interventions

The temporal variations observed at an individual and group level were suggestive of key considerations for sitting-reduction

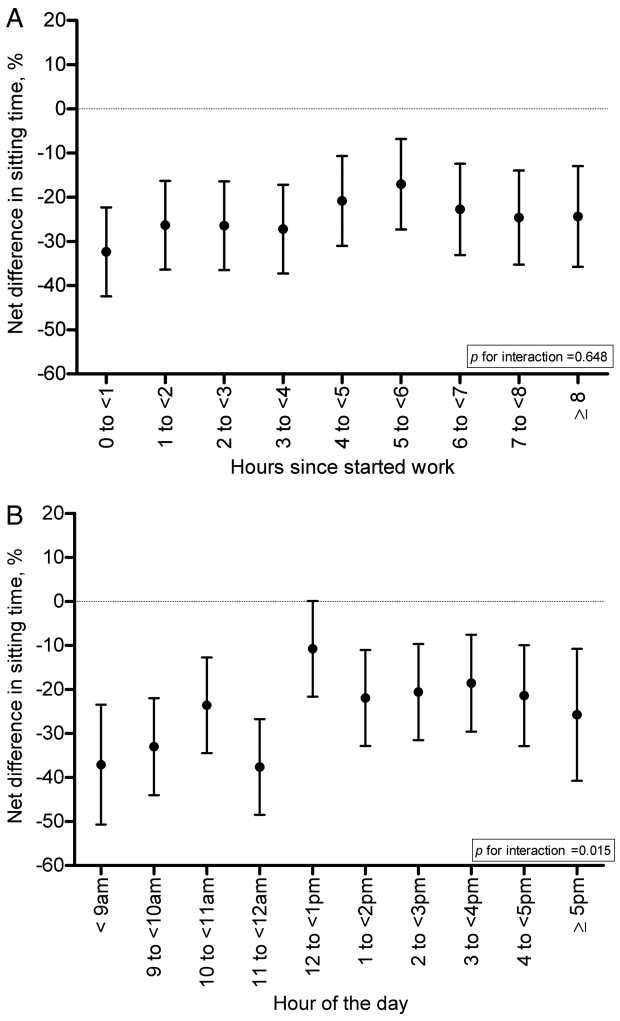


Figure 3 Intervention effects (intervention change minus control change) on percentage of workplace time spent sitting by (A) hour since starting work and (B) hour of the day.

interventions. Specifically, effects by time since starting work were not observed (suggesting fatigue may not be a primary driver of the changes), whereas effects of time of day were observed (suggesting that issues around how workers structure their day and their breaks may be important). Here, morning was a particularly important period of change, with the least change occurring between 12:00 and 13:00 (a common lunch period in the office environment). The correlates of these changes, including the influence of workplace, social norms and peer support, should be investigated in future research.

The accumulation of sedentary time[11 12 26] and temporal patterns[15] has been described cross-sectionally; however, we are among the first studies to examine these changes in an intervention. Additional strengths of the study include analysis of activity outcomes directly relevant to the intervention messages given and the novel application of methods and measures used in other disciplines to this context. The future use of these methods within intervention and observational physical activity and sedentary behaviour research will provide a more comprehensive understanding of time spent in these behaviours and their potential impacts on health.

Limitations of the study include the non-random allocation of participants and the study not being powered a priori on these secondary analyses. Inadequate sample size may have contributed to the non-significant intervention effects for bout number and interactions by hour of the day. Further, in this study, the roles of the participants in the intervention group (predominantly administrative) differed from those in the control group (predominantly managerial), which may have impacted upon the type of work and tasks undertaken. Owing to the small sample size, there was a limited capacity to adjust for potential confounders, therefore intervention effects could have been overestimated or underestimated in this non-randomised trial. Finally, qualitative data were collected to determine feasibility and acceptability of the intervention as well as the participants most favoured intervention component (reported in the main outcomes paper[8]). However, data were not collected to qualitatively describe the context of the change to extricate the effects of the environmental strategies (ie, the sit–stand workstations) from the organisational level support and individual behavioural change strategies. Such information may have helped to explain the wide individual variability observed.

In conclusion, the concepts presented in this deconstruction of the effects of a workplace sedentary behaviour intervention have important implications for strengthening the understanding of behaviour and behavioural change, with the findings providing important insights into the success of the intervention messages in achieving the desired behavioural change. The findings suggest that interventions that address both sitting bout duration and the number of sitting bouts (ie, fewer and shorter bouts) can be effective in reducing total workplace sitting time. Furthermore, focusing on time of day rather than time since starting work may be more beneficial for adopting change across the workday.

What are the new findings?

- We used activity monitor data from an intervention that successfully reduced total workplace sitting time to investigate—for the first time in an intervention context—how and when the reduction occurred, as well as the individual variability in the change.
- We found that, in line with the intervention messages given, the intervention group reduced the number and duration of sitting bouts with these reductions occurring across the day, though there was wide individual variability in these findings.
- The concepts presented in this paper have important implications for strengthening understanding of behaviour and behavioural change.

How might it impact on clinical practice in the near future?

- Excessive sitting is detrimentally related to several health outcomes.
- High amounts of prolonged sitting occur in the office workplace—therefore, this is a key setting for interventions.
- Intervention messages to reduce sitting time in the office workplace should encourage regular interruptions to sitting time (ie, reduce number and duration of sitting bouts) across the workday.

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Contributors GNH conceptualised the study. The study was developed by SKS with GNH, SGT and EGE. SKS completed the data analysis with the support of EAHW and GNH. SGT and SFMC provided data analysis and methodological input. DWD, LE and GNH were chief investigators on the Stand Up Comcare study. SKS was the lead author on the manuscript. EAHW, SGT, DWD, SFMC, EGE and GNH reviewed and contributed to the manuscript draft.

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Competing interests None.

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Intervening to reduce workplace sitting time: how and when do changes to sitting time occur?

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